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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOL. XXXI, PART 3.

PETROLOGICAL NOTES ON SOME PERIDOTITES, SERPENTINES, GABBROS AND ASSOCIATED ROCKS FROM LADAKH, NORTH-WESTERN HIMALAYA, *by* LIEUTENANT-GENERAL C. A. McMAHON, F.R.S., F.G.S.

Published by order of His Excellency the Governor General of India in Council.

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY.
LONDON: MESSRS. KEGAN PAUL, TRENCH, TRÜBNER & Co.

MDCCCCI

CALCUTTA:
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
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INTRODUCTION.

The peridotites and serpentines described in the following pages are found intrusive in the tertiary volcanic series of Ladakh, North-Western Himalaya.

Some of the specimens were collected by the late Dr. Ferdinand Stoliczka, and the rest by Messrs. R. Lydekker, F.R.S., F.G.S.; R. D. Oldham, A.R.S.M., F.G.S., and T. D. La Touche, and this collection of rocks has been lent to me for description by the Geological Survey of India.

Dr. Stoliczka's reference to the rocks of the Púga valley will be found at p. 128, Vol. V, Memoirs, Geol. Surv. Ind. "These quartzose schists," Dr. Stoliczka writes, "form both sides of the Púga valley and become towards the epidote rocks somewhat chloritic, and even garnetiferous. They dip against these epidote rocks where they are visible in the eastern part of the Púga valley.

The axis of Cunningham's *Trans-Himalaya* or *Tsomoriri range* consists here of a series of *epidote*, *diallage* and *serpentine* rocks.

From their dark colours these rocks have sometimes been referred to as *basalts*, but they have certainly nothing to do with these more recent volcanic rocks. At first coming to the camp on the Púga stream we met with an epidote rock, consisting of crystallized or granular masses of *epidote*, *quartz* and *albite*. The epidote when crystallized occurs in short prisms of yellowish or bright green colour.

It is often replaced by *diallage* occurring in the same manner in short laminar prisms and forming a beautiful *syenite-like* rock. Somewhat farther to the north the epidote disappears altogether, and the *diallage* is often found disseminated through a dark green serpentine mass, and in this way forming a very peculiar rock which by many geologists, especially in the Apennines and Southern Alps, would be called *gabbro;* the Himalayan agrees exactly with the Alpine rock. *Diallage* occurs besides in large lumps, and very seldom is any *bronzite* to be seen here. The serpentine rock contains also sometimes sparingly zeolitic and felspathic minerals, and varies greatly in colour. Further to east it is occasionally to be found in serpentine-schist and purer in thin veins. In the Púga valley itself no stratification whatever is perceptible in the whole series of these last-mentioned rocks: they have a truly massive structure.

What is still remarkable and perhaps worthy of notice are large spheroidal masses of quartz, which, in addition to numerous quartz veins occur throughout the serpentine rock."

The following specimens collected by Dr. Stoliczka are described in the following pages:—

No. 94—210.*	Gabbro from the Púga valley, Ladakh.
" 94—211.	Gabbro from the Púga valley, Ladakh.
" 94—213.	Peridotite (Lherzolite), Makha river, Ladakh.
" 94—214.	Peridotite, Púga valley, Ladakh.
" 94—215.	Peridotite (Saxonite), Púga valley, Ladakh.
" 94—216.	Serpentine after picrite, Púga valley, Ladakh.
" 94—225.	Serpentine, from Hanli (Rupshu).

* The numbers given in this paper are those borne by the specimens in the Geological Survey Museum, Calcutta.

Mr. R. Lydekker's account of the "southern tertiary boundary and the large series of volcanic rocks met with along this line" will be found at pp. 111-115, Memoir of the Geology of Kashmir (Memoirs, Vol. XXII, Geol. Surv. Ind.).

"At the north-western extremity of the tertiary zone," Mr. Lydekker writes, "the purple shales of Páskim are overlain by a great mass of basaltic trap, or lava, which in this region consists of greenish anamesite, weathering to a pale-brown colour. Although there is no visible instance of the intrusion of the trap into the beds of the sedimentary rocks, yet the relations of the two are such as to indicate that the trap is the newer rock. It has, however, been already shown that trap pebbles are contained in the higher tertiaries to the south-east, and it may, therefore, be pretty safely inferred that the emission of the trap took place during some part of the time of the deposition of the tertiaries" (p. 111).

The band of trap has in places, as at Shargol, a width "as much as ten miles." It is occasionally "much mixed up" with altered tertiary sedimentary rocks, the "remnants of the sedimentary tertiaries which probably once extended continuously over the whole area, but which have been broken up and altered by the eruption of the volcanic rocks."

Mr. Lydekker traces the outcrop of the trap from point to point, but the details need not be given here; and he notes that "in the neighbourhood of Lámayúru" it is "much involved with palæozoic rocks."

"The trap in the above-mentioned area," Mr. Lydekker continues (p. 112), "has been described as composed of fine-grained anamesites, greenstones, basalts, serpentines, and a few amygdaloids and, according to Dr. Stoliczka, of gabbro and diallage rocks. No porphyritic trap occurs, and when worn, most of the pebbles acquire a dark-brown glaze."

The traps gradually die out to the westward of the Zánskar river, and the "main mass of the sedimentary tertiaries comes into direct

contact with the carboniferous rocks." "To the south-eastward of Skiu the southern tertiary boundary runs near the right bank of the Markha river" . . "In the valley of the Markha along this boundary line, numerous small masses of trap are met with, which is generally of a more crystalline structure than the trap to the westward of the Zánskar river; and it is probably pebbles of this trap which are included in the higher tertiary conglomerates. In places, as on the upper Gya river, this trap has burst through the pre-tertiary rocks, and frequently has included in itself masses of the latter crowded with crinoids. To the south-east of the Gya river the band of carboniferous rocks dies out, and the tertiaries on both their borders are in direct contact with the older crystallines. From a little to the westward of the Púga river to the extreme easterly limit of Kashmir territory, an irregularly wedge-shaped mass of the trap separates the sedimentary tertiaries from the older crystallines, and it is near the southern border of this trap that the extensive mineral deposits of the Púga valley chiefly occur" (p. 113).

At page 115, the author notes the occurrence in the Marpo ravine in the Dras valley of a "serpentine, indistinguishable from that of Páskim," which he thought might "belong to the palæozoic traps."

The following specimens collected by Mr. R. Lydekker are described in the following pages :—

No. 94—212.	Gabbro from Peak D. 24, Ladakh.
" 94—217.	Peridotite (Lherzolite) from Markha valley, Ladakh.
" 4—210.	Serpentine (Bowenite), Skiu valley, Shigar.
" 94— 29.	Hornblende-rock from Ladakh.
" 94—218.	Volcanic ash from Wangat, Ladakh.
" 94—224.	Fine-grained ash from do. do.

Mr. R. D. Oldham writes as follows regarding "*The Indus Valley Tertiaries*" in the Records, Geol. Surv. Ind., Vol. XXI, p. 154 :—

"As these have already been described by Mr. Lydekker more fully than I could do, I shall confine myself to considering the conclusions that may be drawn from them.

To begin with the serpentine rocks: both Dr. Stoliczka and Mr. Lydekker speak with uncertain voice regarding their mode of origin, but both convey the impression that they form a large intrusive mass, though in both descriptions there are not wanting indications that the authors did not altogether accept this conclusion.

I crossed these rocks once on the section from Púga to Maya and again between Leh and Kashmir. In both cases I found beds of clastic origin, ashes and agglomerates interstratified with traps. To take the first named section: starting from Púga the first rock seen, after leaving the gneiss, is a serpentinous slate; this is succeeded by a conglomerate or breccia of slate and limestone, the fragments all flattened by pressure and traversed by an imperfect cleavage, and fine-grained laminated beds with fragments of rock included. The matrix of these rocks contain many small fragments of pyroxene. Further on the volcanic facies becomes more marked, and we have tuff and ashes with dense pyroxenic traps, all of which have undergone more or less complete serpentinous change.

Where the stream bends to the east, the dip of the beds, which had been northwards, changes to south, but is very obscure. At the bend of the stream a bed of limestone occurs among the volcanics, but is cut up by faults into small patches of a few yards across scattered up and down the hillside in almost perplexing manner, and this intense cutting up of the beds is sufficient to account for the absence of distinct and continuous bedding in the traps.

As to the interpretation of this section, it would at first appear that from Púga to the bend in the stream there was an ascending and below that a descending section; the crystalline limestone occupying the centre of a synclinal. But lower down-stream the same limestone occurs on the hills south of the valley above the dense traps, and to judge by the fragments brought down by streams, is overlaid by beds very like those seen in contact with the gneiss.

On the section along the Kashmir road these features are not so well seen, but even there ash-beds can be found among the traps.

So there can be but little doubt that we have here a true volcanic series.

I must not be misunderstood to deny the existence of intrusive rocks. I have myself seen these some miles south of Karzok on the Tso Morari and as far north as Shushal. Intrusive rocks doubtless occur among the volcanics, indeed this is but what might be expected and may doubtless account for the ambiguity in the two published descriptions.

As to the lithology of the beds, beyond what is implied in the above passages, nothing need be added to the descriptions of Dr. Stoliczka, Mr. Lydekker, and later of Colonel McMahon."

The microscopical examination of the following specimens collected by Mr. R. D. Oldham are described in this paper, *viz.* :—

No.	8—278.	Lherzolite from the Púga valley, Ladakh.
"	8—276.	Serpentine after Troctolite, Púga valley, Ladakh.
"	8—279.	Porphyritic diorite, from N. of Chang La, Ladakh.
"	8—280.	Porphyritic diorite. Junction of Chang and Inchine valleys, Ladakh.
"	8—281.	Porphyritic diorite. Junction of Chang and Inchine valleys, Ladakh.
"	8—271.	Volcanic ash, from the Púga valley, Ladakh.
"	8—272.	Volcanic ash, from do. do.
"	8—275.	Volcanic ash, from do. do.

The following specimens collected by Mr. T. D. La Touche are also described :—

No.	8—293.	Serpentine from valley W. of Sirsa La, Zánskar.
"	8—294.	Serpentine from do. do.

The second edition of Medlicott and Blanford's Manual of the Geology of India by Mr. R. D. Oldham contains at page 346 the following reference to the Ladakh igneous and volcanic rocks :—

"In the sections eastwards of Leh, conglomerates are said to occur near the upper limit of the series, and these conglomerates contain pebbles of the volcanic beds, which will presently be described, and of nummulitic limestone. The occurrence of these last shows that the beds had locally been elevated and exposed to

denudation, while elsewhere the process of deposition was going on continuously.

In the central portion of the exposure the sedimentary beds are in direct contact with the older rocks along their south-western margin, but at either extremity they are separated by a great series of volcanic rocks of a very basic type. There can be no doubt that these rocks, which form the upper limit of the tertiary system of this region, are in the main contemporaneous eruptive products, as they include beds of volcanic ash and agglomerate,[1] but there are also numerous intrusive masses associated with the bedded traps. Basic trappean intrusions are also found in the pre-tertiary rocks south-west of the boundary, which are evidently connected with these same eruptive rocks. These intrusions are interesting as, at Púga and in the Markha valley south of Leh, they are composed of peridotite, until lately the only recorded instances of ultra-basic rocks having been found in India."[2]

The microscopical examination of the specimens enumerated above shows that many of them are ultra-basic peridotites, and others are serpentines formed by the more or less complete alteration of olivine rocks. Both groups belong to the plutonic class of igneous rocks; their structure is completely holo-crystalline, and they have never flowed out on the surface of the earth as lavas. The same remark applies to the gabbros.

The association of these holo-crystalline plutonic rocks with volcanic beds of lava and ash, as in the Púga valley, must be purely accidental. The holo-crystalline igneous rocks are evidently, as suggested by Mr. Oldham, intrusive in the volcanic series, and may possibly have no direct genetic relation to them. It is quite a common feature in Himalayan geology to find diverse igneous rocks following each other along the same planes of weakness.

As will be seen from my detailed description of the porphyritic diorite collected by Mr. Oldham (which was not found *in situ*),

[1] C. A. McMahon, Records, XIX, p. 118 (1885); R. D. Oldham, Records, XXI, p. 154 (1888).

[2] C. A. McMahon, Records, XIX, p. 115 (1885).

I regard this rock as a hypogene representative of a volcanic rock rather than a volcanic rock itself. The hornblende-rock, said to be an altered pyroxenite, is also a hypogene rock. It is doubtful whether any of the rock specimens described in this paper include a true lava.

The samples of ash sent me are from the Wangat and Púga valleys. As these rocks have been much altered by the combined effects of pressure, aqueous infiltration, and the contact action of intrusive igneous masses, it is in some cases difficult to say decidedly whether one is dealing with an altered ash, or a metamorphosed lava: and, in other cases, whether the rock is an ash or a very fine-grained fragmentary rock containing some splintery pieces of acid lavas, such as felsites and rhyolites.

One of the serpentines from Shigar (4—210) collected by Mr. Lydekker is of especial interest as it proves to be the rare variety called bowenite or pseudo-jade. The description of this rock is given at page 11.

PERIDOTITES.

No. 8—278. Peridotite (Lherzolite) from the Púga valley, Ladakh; collected by R. D. Oldham, F.G.S.; Sp. G. 2·865.

This is a much altered rock composed of olivine, monoclinic pyroxene, a little enstatite, bastite, diallage, grains of magnetite, and secondary decomposition products.

The olivine is traversed by very numerous canals of serpentine and is cut up into rounded grains.

The pyroxene has also suffered much from decomposition. It is dull and polarizes very feebly. Like the olivine it is penetrated by infiltration canals, but they are not so numerous as those in the former mineral. They are filled with a colourless serpentinous mineral inert in polarized light. The diallage and bastite possess hardly any double refraction.

The olivine grains are sometimes fringed with radiating tufts of fine needles, with oblique extinction, which are evidently some form

of amphibole. Isotropic structureless mineral matter often intervenes between the serpentine proper and the pyroxene and bastite. I think it is identical with that stopping the canals in the pyroxene and is a variety of serpentine.

No. 94—213. Altered Peridotite (*Lherzolite*) from the Markha river, Ladakh; collected by the late Dr. Ferdinand Stoliczka; Sp. G. 3·155.

This specimen has already been described by me in the Records, Geol. Surv. Ind., Vol. XIX, p. 117, and I quoted in that paper Dr. Stoliczka's and Mr. Lydekker's references to it in the Mem., Geol. Surv. Ind., Vols. V, p. 343, and XXII, p. 107, from which it appears that it is intrusive in rocks of eocene age.

This peridotite is composed of olivine, enstatite, augite, picotite and magnetite. Olivine is very abundant, the major part of the rock consisting of it. Fine aqueous canals traverse it in all directions, but beyond the formation of these channels serpentinisation has made no progress and has left the body of the mineral quite fresh. The augite and enstatite, on the other hand, exhibit the commencement of the first stages of conversion into diallage and bastite.

Cracks in the rock are stopped with a colourless fibrous serpentine.

No. 94—214. Altered Peridotite, from Púga valley, Ladakh; collected by the late Dr. Ferdinand Stoliczka; Sp. G. 3·039.

This rock consists of serpentine and diallage with a considerable amount of secondary magnetite. The serpentine and diallage present their usual characters and do not need detailed description. Serpentine is the most abundant mineral, but diallage does not fall very far behind it.

No. 94—215. Partially altered Peridotite (*saxonite*) from the Púga valley, Ladakh; collected by the late Dr. Ferdinand Stoliczka; Sp. G. 2·857.

This rock was described by me in the Records, Geol. Surv. Ind., Vol. XIX, p. 115. It is composed of olivine, serpentine, enstatite, pyroxene and picotite.

Olivine constituted the major part of the original rock. The proportion of fresh olivine to serpentine in the hand-specimen examined varies very much. In places olivine preponderates and the field of the microscope consists of fresh olivine traversed by a network of narrow canals filled with serpentine. In other places the field consists of serpentine with small remnants of unaltered olivine left in it here and there.

The enstatite is colourless and polarizes feebly. It is cut up by canals of serpentine and has evidently sustained considerable strain and pressure. The lamellæ are sometimes bent and strain shadows are not uncommon. Some of the slices exhibit a lamellar inter-growth of monoclinic pyroxene and enstatite similar to that described by Rosenbusch.[1] They can only be distinguished from each other in polarized light.

The slices also contain some allo-triomorphic crystals of pyroxene and some picotite. The structure of the rock is holo-crystalline.

No. 94—217. Peridotite (*Lherzolite*) from Markha valley, Ladakh; collected by R. Lydekker, F.R.S.; Sp. G. 2·976.

This rock is composed of olivine, enstatite, augite and picotite. Olivine is by far the most abundant mineral and enstatite comes next.

The olivine is traversed by a perfect net-work of serpentine canals, but is otherwise quite fresh. The enstatite has also suffered to some extent in this way, but not so much as the olivine. Both the enstatite and the augite are nearly colourless in transmitted light.

The structure of the rock is holo-crystalline.

Serpentines.

No. 4—210. Serpentine, species Bowenite, from the Skiu valley, Shigar; collected by R. Lydekker, F.R.S.

Mr. Lydekker in his Memoir on the Geology of Kashmir (Memoirs, Geol. Surv. Ind., Vol. XXII), at page 189 refers to this serpentine as follows:—"In these shaly rocks (of carboniferous age) somewhere

[1] Microscopical Physiography of the rock-making minerals, by Rosenbusch. Translated by Iddings; p. 205.

high up on the peak named Mango-Gusor (20,635 feet) there occurs a greenish-yellow calcareous serpentine, fragments of which are found fallen into the ravines below. This rock, which appears to be similar to the one from the presumed Kuling series of the upper Wardwan valley, is extensively sought by the Shigar people for the manufacturing of small cups, etc., and will be further alluded to in the chapter on economic geology."

The occurrence of the rock in the upper Wardwan valley is referred to at page 150 of the Memoir as follows:—" Between the pass and Rangmarg, in the upper Wardwan valley, there occurs on the right bank of the river another mass of the same granitoid-gneiss, overlain to the south and west by dark slates and the characteristic supra-Kuling rocks. These slates contain bands of a greenish serpentinous rock identical with a similar rock underlying the supra-Kuling series of Shigar, and it is accordingly presumed that these rocks are the partially altered Kuling series."

The passage in the chapter on economic geology alluded to in the extract given above is as follows:—" From a calcareous serpentine or verd antique occurring in the (probably) Kuling rocks of the neighbourhood cups and small vases are extensively manufactured at Shigar, in Baltistan. The rock is locally known as yesham, or jade, and is of bright apple-green colour, sometimes shading off to yellow, or bottle-green. A specimen of one of these cups, presented by the present writer, is in the Indian Museum and another presented by Mr. Drew, in the Geological Museum, Jermyn Street." (Memoirs, Geol. Surv. Ind., Vol. XXII, p. 339.)

The hand-specimen in the Calcutta Museum, No. 4-210, is coloured on the weathered surface a dull greenish-yellow inclining, on freshly broken faces, to a pale sulphur yellow. Its specific gravity is 2·48 [1] and its hardness 5.

In order to compare the rock with the typical bowenite from

[1] I am responsible for this determination and for the specific gravity of Nos. 8—280 and 8—294. I operated on pieces of suitable size with the aid of a Chemical balance. The Sp. G. of the other specimens was determined in the Geological Survey Office, Calcutta.

Afghánistán described by me in the Mineralogical Magazine, Vol. IX, p. 187, I have made an analysis of the Shigar rock, which I give below (No. 1) side by side with that of the Afghán bowenite made by Mr. G. T. Prior, M.A., F.G.S., F.C.S., of the Mineralogical Department of the British Museum :—

	No. I, from Shigar.	No. II, from Afghánistán.
Silica	41·13	44·73
Magnesia	43·65	42·64
Alumina	1·23	0·32
Iron	1·49	0·33
Lime	·17	trace
Manganese	...	...
Water	12·46	12·21
Total	100·13	100·23
Sp G.	2·48	2·59
H.	5·0	5·0

It will be seen from the above that both rocks are substantially the same in composition. In both the hardness is considerably in excess of ordinary serpentine.

None of the specimens of the Afghán mineral that I have seen have the peculiar sulphur-yellow colour of the Shigar rock. On the contrary they vary from a dark greenish-grey to pale sea-green mottled with white and apple-green. Mr. Lydekker did not see any of the Shigar bowenite *in situ*. His specimens had fallen from the Mango-Gusor peak and were picked up in the ravines at its foot. All the blocks from this locality appear to have been of yellow colour. Mr. Lydekker saw, however, the apple-green variety at Shigar to which place it is brought in order to be made into cups. He did not see it *in situ*, but doubtless it is found somewhere in the neighbourhood. The apple-green variety, Mr. Lydekker states, sometimes shades into yellow or bottle-green.

I trust that some future explorer will find the actual outcrop of bowenite and ascertain its exact mode of occurrence. Is it in dykes, sills or in veins? Does the apple-green variety shade off into the sulphur-yellow variety or do they form distinct outcrops? In what

rocks does it appear and at what period did the intrusion of bowenite take place?

Under the microscope thin slices of the Shigar bowenite, when viewed between crossed Nicols, exhibit scattered specks of doubly refracting mineral matter on a dark back-ground very suggestive of a star-spangled sky on a clear dark night. On revolving the Nicols the bright points become dark and the dark ones bright. The slices contain no isotropic matter except in veins.

The doubly refracting particles are of microscopic size and are without a trace of crystalline form.

Thin slices contain small granules of magnetite, and are dotted over with irregular opaque spots, white in reflected light, the exact mineral character of which is uncertain. Some of the serpentine occurs in strings having a transverse fibrous structure.

The double refraction of the serpentine in the Shigar bowenite is low. It possesses straight extinction. The character of the depolarization is positive, and its refraction lies between 1·560 and 1·606.

The microscopic examination of thin slices does not afford any clue as to the nature of the original minerals out of which the serpentine was formed. All original structures have been obliterated. Even "the curved feathery and sheaf-like crystals," seen in the bowenite of Afghánistán, and which I referred to olivine as their parent, are absent in the Shigar rock.

I give for comparison reproductions of photographs of thin slices of the two rocks as seen under the microscope between crossed Nicols: *viz.*, fig. 1, Pl. 17, Shigar bowenite; figs. 2 and 3 small and large grained Afghán bowenite.

No. 8—276. Serpentine after a troctolite inclining towards picrite, from Púga valley, Ladakh; collected by R. D. Oldham, F.G.S.; Sp. G. 2·785.

The hand-specimen is a dark greenish-grey compact rock spotted with white.

[1] Nothing is known about the mode of occurrence of the Afghán bowenite.

The original rock appears to have been a holo-crystalline mixture of olivine, monoclinic pyroxene, and labradorite, the olivine largely predominating. The olivine has been almost wholly transformed into serpentine, pale yellow in transmitted light. It exhibits the usual mesh-structure in polarized light, and eyes of unaltered olivine are visible here and there. Marginal deposits of magnetite are abundant as in normal serpentine.

The pyroxene and labradorite are both allo-triomorphic. The pyroxene is very highly altered and steatitic. In only one slice, No. 1994 of the Calcutta Geological Museum microscope slides taken from No. 8·277, is any of the pyroxene at all fresh. The labradorite exhibits multiple twinning, the maximum extinction being $28\frac{1}{2}°$. Some of the felspar is traversed by fine infiltration canals which have penetrated into it from the serpentine.

The hardness(4) and Sp. G. of the rock are both rather high for serpentine.

No. 8—293. Serpentine, from the valley west of Sirsa La; collected by T. D. LaTouche; Sp. G. 2·638.

The bulk of this rock is made up of serpentine after olivine. The conversion of the latter mineral has been complete and no eyes of olivine have been left in the serpentine. The thin slices examined also contain remnants of augite, a finely fibrous serpentine, picotite and some magnetite. The pyroxene fragments are mere remnants of large crystals, the major portions of which have been converted into serpentine by aqueous agents. The augite exhibits a single cleavage, and in some cases the angle of extinction measured from that cleavage is as low as from 6° to 11°. This may be due to partial uralization.

The only mineral that calls for any comment is the finely fibrous serpentine. It is rather suggestive of bastite, but as it has evidently been derived from augite and not from enstatite, it cannot be referred to that mineral. It is almost colourless in thin sections, it has

a feeble double refraction and has the refractive index of serpentine. In converging polarized light I could get no definite results even with a $\frac{1}{12}$ immersion lens in oil. This fibrous serpentine generally surrounds remnants of corroded augites and is evidently the product of the decomposition of large crystals of this mineral. (Figs. 4 and 5, Plate 18.) This conclusion is confirmed by two observations. The first is that a large augite (Fig. 5, Plate 18) is penetrated by solution veins which are now filled with the fibrous serpentine and this is continuous with the fibrous serpentine in which the augite is imbedded. The veins widen out towards the margin of the augite like the mouths of rivers, and the fibrous serpentine in them passes into the fibrous serpentine outside without a break of any kind. The second fact is that though the fibrous serpentine has generally straight extinction, I have observed one or two cases in which the extinction is oblique. The latter fact seems to indicate that the serpentine was derived from a monoclinic pyroxene, but that its conversion in some cases was not quite complete.

This fibrous serpentine is I think a variety of chrysotile.

No. 82—94. Serpentine, from the valley west of Sirsa La, Zánskar; collected by T. D. La Touche.

The two hand-specimens consist of serpentine with a vein of white soda-zoisite running through it.

The dark portions of the hand-specimens are composed of serpentine with allo-triomorphic crystals of enstatite and magnetite imbededed in it. No eyes of olivine remain.

The following note was made by Mr. F. R. Mallet, F.G.S., F.C.S., in the Calcutta Geological Survey Laboratory book, p. 129, under date 19th January, 1889:—

"Sp. G. 3·442 (Mr. Blyth)
H. 7.

Fuses easily to a blebby bead with strong intumescence. When treated for two and a half hours with strong hydrochloric acid 61·2

per cent. was dissolved (Mr. Blyth). After ignition gelatinizes with hydrochloric acid.

Contains abundant silica, alumina and lime, a very little iron, magnesia, soda, and a little water.

In all the above characters the mineral agrees with *zoisite*, except that it is decomposed (without ignition) by hydrochloric acid. A specimen of zoisite from Valtigl, Tyrol (M. 1639) when heated in hydrochloric acid for 2½ hours had 10·41 per cent. dissolved. After heating for 2½ hours in strong sulphuric acid 8·4 per cent. only was dissolved of I-177," [*viz.*, the white mineral in 8-294 under consideration. New numbers seem to have been given to the specimens after their transfer to the Geological Museum.]

The specific gravity 3·442 and hardness of 7, alluded to above, appears to refer to the white mineral (zoisite) and not to the rock specimen as a whole. I found the Sp. G. of the serpentine to be 2·67, and the zoisite 3·483, which latter corresponds very closely to Mr. Blyth's figures. I operated on a small piece with the aid of a chemical balance. Dana gives the Sp. G. for "ordinary" zoisite as 3·226 to 3·381 (Text-book of Mineralogy by E. S. Dana, 1898, p. 438). The slight increase in the Sp. G. of the Zánskar mineral is doubtless due to the presence of the oxide of iron, numerous dots of which are to be seen in thin slices under the microscope.

Some would probably call the mineral under consideration saussurite and the term would not be inappropriate. Dana puts the hardness of saussurite as 6·5 to 7 and the Sp. G. as ranging from 3 to 3·4 (System, 6th Ed., 1892, p. 515). "In composition it often approaches zoisite, of which it has been regarded as a soda-bearing variety."

As the name saussurite appears to be given to minerals which differ much from each other and as "it is rarely, if ever," Dana states, "a homogeneous mineral," I think it will be best to call the white substance in the vein running through the Zánskar serpentine

a soda-zoisite. Its optical characters agree with zoisite. Part of it is clear and transparent, but here and there it is clouded and opaque. Its double refraction is feeble, and often it has no action on polarized light. Its refraction is high, namely, higher than 1·630, and lower than 1·740. The refraction of zoisite ranges from 1·696 to 1·702.

No. 94—216. Serpentine after picrite from Púga valley, Ladakh; collected by the late Dr. Ferdinand Stoliczka; Sp. G. 2·825.

This rock is composed of serpentine, olivine, augite, and felspar; the first named being the most and the felspar the least abundant mineral.

The serpentine contains eyes of olivine, and exhibits the usual mesh-structure and other characteristics of serpentine derived from that mineral. The infiltration-canals running through it are, as usual in olivine-serpentine, lined with banks of magnetite thrown down as a chemical deposit in the course of the decomposition of the olivine and the formation of the serpentine.

The augite is colourless in transmitted light and is probably malacolite or an allied species. It rarely exhibits decided cleavage, but when it does, it is a close, single cleavage resembling that of diallage. It is traversed by occasional canals of serpentine; but as usual in such cases, the pyroxene has not yielded as readily to aqueous agents as the olivine.

The felspar is much decomposed, but it shows the albite twinning of plagioclase. Judging from the angles of extinction (the highest obtained in suitable cases was 25°) and from the fact that it contains infiltration-canals, it appears to belong to the labradorite species.

No. 94—225. Serpentine, from Hanli (Rupshu); collected by the late Dr. Ferdinand Stoliczka; Sp. G. 2·604.

This is an ordinary serpentine rock. It exhibits the usual mesh-structure, and is composed of the minerals serpentine, magnetite and

titaniferous iron. It also contains ferric oxide. The hand-specimen has a slicken-sided appearance and under the microscope the rock is seen to have been subjected to pressure, shearing, and here and there to contortion.

GABBROS.

No. 94—210. Gabbro; collected by the late Dr. Ferdinand Stoliczka, in the Púga valley, Ladakh; Sp. G. 3·076.

When examined under the microscope this rock is seen to be composed of augite, diallage and saussurized plagioclase.

Nearly the whole of the augite has been converted into diallage and only portions of the crystals have escaped change. Both minerals polarize brilliantly in colours of Newton's second order. They contain tabular allo-triomorphic patches of brown hornblende rather suggestive of biotite. The pleochroism of the hornblende is somewhat feeble; and between crossed Nicols it changes from a dark blackish-grey to a pale orange-yellow of the first order. It shows no cleavage. With convergent polarized light it gives a biaxial bar. It looks like a secondary product of decomposition.

The felspar—an altered plagioclase—has been more or less metamorphosed into zoisite. In hardness it is about 6·5 of Mohs' scale. A chip of it sank in cadmium boro-tungstate, its specific gravity is therefore greater than 3·28. This agrees well with zoisite, which has a hardness of 6 to 6·5 and a specific gravity of from 3·226 to 3·381.

Between crossed Nicols the zoisitic felspar ranged from a feeble yellowish white of the first order to isotropic.

The structure of the rock is holo-crystalline.

No. 94—211. Gabbro; collected by the late Dr. Ferdinand Stoliczka, in the Púga valley, Ladakh; Sp. G. 2·959.

This rock is a holo-crystalline mixture of diallage and labradorite felspar.

The diallage is very typically developed. It usually polarizes brilliantly in colours of Newton's first order. Here and there it has suffered alteration to hornblende and in other places into zoisite.

The felspar, judging from the angle of extinction from the twinning plane of albite twins, is labradorite. The maximum extinction in five suitable cases was 33½°. It has suffered more or less conversion into zoisite, the change being partial in some cases but complete in others.

No. 94—212. *Gabbro*, from Peak D. 24, Ladakh; collected by R. Lydekker, F.R.S., F.G.S.; Sp. G. 3·195.

This rock is composed of olivine and diallage with some picotite, the first mentioned mineral predominating.

The olivine is fairly fresh and polarizes brilliantly in the blue, red, and yellow of Newton's second order. It is traversed by some aqueous canals but serpentinisation has hardly commenced.

The diallage, on the other hand, is extremely dull between crossed Nicols and polarizes feebly in shades of grey.

The rock has evidently sustained considerable pressure. The olivine is much cracked, and here and there puts on a micro-tessellated structure imitative of the tessellated quartz of the Himalayan granites. Both the olivine and the diallage exhibit strain shadows. Some of the latter also show an interrupted foliation distinct from the fine cleavage.

PORPHYRITIC DIORITE.

Collected by R. D. Oldham, A.R.S.M., F.G.S.

No. 8—279. Locality, 2 miles North-East of Isul Tak, North of Chang La, Ladakh.

No. 8—280. Locality, junction of the Chang and Inchine valleys, Ladakh.

No. 8—281. Locality, junction of the Chang and Inchine valleys, Ladakh.

The above specimens are all samples of identically the same rock and it will be convenient to describe them together.

The matrix appears to the unaided eye to be compact in structure and varies from a dark slaty to a dark greenish-grey.

The porphyritic felspars are in thin tabular crystals, the face b (010) forming the platy surface. They sometimes attain a length of 4 centimetres and their average width is about 2, and their thickness from 0·2 to 0·4 centimetres. Owing to traction, or pressure, whilst the rock was in a plastic condition, the b (010) faces are generally in the same plane, so that when the fractured surface of the hand-specimen coincides with that plane, platy crystals only are seen. On the other hand, when the fractured surface of the specimen is at right angles to that plane, only slender, lath-shaped crystals are visible. Both these features are well seen in the hand-specimen 8—281.

The porphyritic felspars, judging from the extinctions measured from the twinning plane in suitable cases, and other features, belong mainly to the labradorite species, though a little andesine appears to be also present. The labradorite belongs to the most acid variety, the highest extinction angle obtained not exceeding 26°.

The orientation of the large felspars is generally speaking approximately parallel, but here and there they locally radiate at various angles up to 90° from this general direction, indicating the existence of local variation in the effects of traction on the flow of the viscid uncooled mass prior to consolidation.

The microscopical examination of thin slices shows that many of the porphyritic felspars possess zonal structure. They have sometimes been cracked and shattered internally and contain marginal inclusions of the magma, which also penetrated them in the form of tongues. The cracks are sometimes filled with chlorite and sometimes with a structureless isotropic substance, which is probably allied to zoisite. Portions of the felspars, in some cases, are fairly fresh. Other crystals are much corroded and some have almost become pseudomorphs of chlorite and zoisite.

The groundmass is composed of allo-triomorphic hornblende, felspar prisms, and iron ores, namely, magnetite, ilmenite, pyrite and limonite.

The hornblende is pleochroic in shades of green and greenish-yellow. It rarely exhibits any cleavage; and it is not at all fresh. It polarizes sometimes in colours of Newton's first order, but a change into chlorite had evidently begun, and had made progress in some individuals. It, or the augite from which it was derived, was evidently one of the last minerals to crystallise out of the cooling magma, for it is micro-poikilitic and generally encloses several small felspars wholly, or partially, within its crystals. Occasionally the amphibole exhibits a tendency to become idiomorphic, but never shows decided crystallographic outlines.

The second generation of felspars vary very much in size, but one that may be considered a fair average specimen measured 0·035 millimetres long by 0·0063 thick. The small felspars alluded to as the second generation, are all either in binary or multiple twins. The extinctions in those intermediate between the microliths and large porphyritic felspars range from $16\frac{1}{2}$ to $20\frac{1}{2}$ degrees; and the microliths from 0° up to $22\frac{1}{2}^\circ$. Those extinguishing from 0° to 6° are probably oligoclase and the others acid labradorite with some andesine or albite.

None of the above three specimens were found *in situ*, but came from blocks in recent deposits. I described[1] a porphyritic volcanic rock under the name of basalt-porphyry from the ridge above Bhandal, in the Chamba territory on the borders of the Kashmir State, which, macroscopically considered, very much resembles the rocks under consideration. The basalt-porphyry exhibits porphyritic plagioclase felspars starred about in a dark-grey compact matrix, which under the microscope is seen to be a matted mass of felspar microliths in a finely granular base or groundmass. The specific gravity of the Bhandal rock averaged 2·89; that of

[1] Rec. Geol. Surv. Ind., Vol. XVIII, p. 96.

No. 8—280, determined with the aid of a chemical balance, was 2·90. Very possibly the porphyritic diorite of Ladakh may be the hypogene representative of some such volcanic rock as the Bhandal porphyrite and its hornblende may be paramorphic after augite.

94—29. Hornblende-rock, from Ladakh; collected by R. Lydekker, F.R.S., F.G.S.; Sp. G. 3·095.

This is entered in the list as a "Pyroxenite almost completely changed to hornblende-rock." This short description is doubtless correct and may be based on observations in the field. The rock is said to be of pre-silurian age.

Under the miscroscope the thin slices are seen to be composed of hornblende with some magnetite. The hornblende is in shapeless crystals or grains. In transmitted light and in thin slices it varies from colourless to a pale sage-green and pale blue-green. A single cleavage is sometimes well developed, but it is generally very imperfect. This is crossed by transverse cracks which are inconstant in direction. The angle at which these cracks cross the first cleavage sometimes suggests the cross-cleavage of augite and sometimes that of hornblende. Pleochroism is not strong and the changes are from pale yellowish-brown to a pale brown-green. The angle of extinction varies from 15° to 39°. Between crossed Nicols some sections are very dull, but some polarize rather brilliantly in the blue, yellow and red of Newton's first order.

The hornblende is not at all fresh, and alteration to zoisite has been more or less set up.

There are also here and there nests of an almost colourless mica. It is evidently a secondary product.

Van Hise[1] has shown that both augite and amphibole change into zoisite. The alteration of amphibole into epidote has long been known and petrologists are familiar with the fact that epidote and

[1] Principles of N. American Pre-Cambrian Geology, by C. R. Van Hise, p. 690.

and zoisite are often intimately associated together. In the case of the rock under consideration, I think it probable that the hornblende was derived by paramorphic change from augite. On this supposition the variation in the angles of extinction could be easily accounted for. The conversion of augite into hornblende would, we might naturally expect, have been more complete in some crystals than in others.

VOLCANIC ASH.

No. 8—271. Volcanic Ash, from Púga valley, Ladakh; collected by R. D. Oldham, F. G. S.

This specimen is dark green in colour and has a specific gravity of 2·915. Judging from the hand-specimen, the rock either possessed an original laminated structure or a pseudo-lamination has been superinduced by pressure.

The microscopical examination of this rock does not enable me to speak decidedly regarding its origin. It was probably a very fine-grained ash, but, if so, aqueous agents acting on it after its deposition have removed all evidence of its clastic origin. The rock now consists of a very fine-grained mixture of chlorite and microgranular epidote (a variety inclining towards zoisite) dotted with magnetite and an opaque substance, white in reflected light, for which there does not seem to be any definite mineral name. It is a product of decomposition and looks like a cross between leucoxene and zoisite. The slice is much permeated by calcite and contains remains of felspars, some of which are triclinic. The rock is probably a highly altered ash.

No. 8—272. Volcanic Ash, from the Púga valley, Ladakh; collected by R. D. Oldham, F.G.S.; Sp. G. 2·873.

This is a very similar rock to the last. It consists of highly altered felspar crystals, or fragments of crystals, scattered about in a groundmass composed of epidote, chlorite, calcite, ferric oxide, and the white opaque mineral mentioned in the description of the

last slice. The felspars have in part been converted into chlorite and otherwise much altered.

The rock is probably a highly altered ash.

No. 8—275. Volcanic Ash, from Púga valley, Ladakh; collected by R. D. Oldham, F.G.S.; Sp. G. 2·873.

The hand-specimen of this rock is greenish grey in colour and is dotted with black augite crystals. Viewed macroscopically it appears to be an undoubted ash.

The microscope confirms this verdict: but at first sight thin slices of the rock when examined under the microscope are in some respects suggestive of a lava.

Numerous crystals of augite, pale brown in transmitted light, which contain inclusions of the groundmass, are penetrated round their edges by tongues, and closely resemble corroded phenocrysts. This impression is rendered stronger by the fact that the material which forms the inclusions and the tongues is identical with the groundmass itself; and all of it is uniformly dotted with minute spots, or patches, of white and opaque mineral matter resembling leucoxene. The tongues, moreover, are continuous with the groundmass. There is no physical break between them suggestive of clastic structure.

This pseudo-corrosion appears to have been produced in the following way. The original rock, I take it, was composed of augite and felspar phenocrysts imbedded in a glassy or felspathic base, and the phenocrysts of augite contained inclusions of this base. Then came the volcanic explosion that formed the ash. The large augites were broken into fragments and were in their passage through the air abraded at their edges by collision with each other. The material of the groundmass, on the other hand, broke up more easily and formed a very fine-grained dust which by subsequent pressure was forced into tongue-like abrasions in the augite crystals. Lastly, there followed aqueous infiltration that caused a segregation of the

titaniferous-iron in the finely comminuted ash, and in the inclusions of the base in the augites. Opaque spots and patches of leucoxene were thus formed in the groundmass, in the pseudo tongues, and in the inclusions. Aqueous infiltration still further masked the clastic character of the rock by converting what remained of the finely comminuted ash into a chloritic-serpentine, fine canals of which not only meander about in the groundmass, but penetrate the augites from side to side.

The augites are nearly all distinctly fragments, though in one case an idiomorphic crystal remains intact. There are also fragments of felspars. They are much altered and contain patches of chloritic serpentinous material and of calcite, or magnesite, and magnetite. The latter is also common in the groundmass.

The rock under description affords a good object lesson of how aqueous agents, acting on finely comminuted ash, may obliterate evidence of its clastic origin. Where the contact action of igneous intrusive rocks follow the action of aqueous agents still greater difficulties may arise. A really good suite of specimens is *sometimes* indispensable to enable a petrologist to say positively whether a rock is a highly metamorphosed ash or a highly altered lava.

No. 94—218. Volcanic Ash, from Wangat, Ladakh; collected by R. Lydekker, F.R.S.; Sp. G. 2·849. The rock occurs with tertiary strata.

This ash has already been described by me in the Records, Geol. Surv. Ind., Vol. XIX, p. 118 (1886). It is a dark-grey fragmental rock with a slight greenish tinge.

Under the microscope the rock is seen to be made up of subangular and splintery fragments which vary much in size. Some of them are fragments of acid volcanic rocks such as felsite, rhyolitic lava, and porphyry. There are also pieces of quartz, felspar, crystalline limestone, and grains of magnetite and titaniferous iron. It is the two last that give the rock its high specific gravity. If we except the iron, which appears to be an original constituent and

not a secondary product of infiltration, none of the fragments were derived from basic lavas or ultra-basic igneous rocks. I have not detected any ferro-magnesian mineral in the slices cut from this specimen. Besides the above-named rocks the thin slices also contain grains of calcite and fragments of quartz and felspar.

The fragments of which the rock is made up are the reverse of fresh, but the alteration set up in them seems to have taken place before the formation of the ash. The thin slices are not stained or streaked by any visible aqueous agents.

The ash reminds me of the ash-like fragmental rock which occurs in the Gupis-Yasin section of the Yasin valley described in my paper on the Geology of Gilgit (Quart. Journ. Geol. Soc., Vol. 56, pp. 357, 358). They must both have been derived from very similar rocks.

No. 94—224. Fine-grained Ash, from Wangat, Ladakh ; collected by R. Lydekker, F.R.S.; Sp. G. 2·754. Said to be of eocene age.

This is a greenish grey and very fine-grained fragmental rock. It is made up of subangular fragments very closely packed together. They are all small, but vary much in relative size. None of them are water-worn and there is no parallelism, or lamination, in their arrangement, the longer axes of the fragments being orientated in all directions.

Some of the fragments can be definitely recognised as lavas, but the majority cannot be identified as such. They consist of angular, subangular, or splintery pieces of quartz, triclinic felspar, crystalline limestone, granite, and schist. Some of the quartz grains contain numerous liquid cavities with movable bubbles and were evidently derived from a granite. Some fragments apparently came from porphyries or rhyolitic rocks.

Tne slices contain dots and patches of red or dark brown ferrite, but no ferro-magnesian mineral, or fragment of a basic igneous rock. Except in its finer grain, and in the absence of magnetite, it very much resembles the last-mentioned specimen. The fragments are

not fresh and are dotted and streaked with on opaque substance, dead white in reflected light, suggestive of leucoxene.

I cannot say decisively from the microscopical examination of thin slices of this rock whether it is a fine-grained grit made up mainly of fragments of igneous rocks, or whether it is of true pyroclastic origin. Three things, however, may be positively affirmed regarding the rock, namely, that it is of clastic origin; that the materials of which it is composed are not water-worn, and that they cannot have travelled far. Presumably, therefore, it is an ash.

EXPLANATION OF PLATES XVII AND XVIII.

Fig. 1. Shigar bowenite as seen under the microscope between crossed Nicols.

Fig. 2. A fine-grained slice of Afghán bowenite under crossed Nicols.

Fig. 3. Large grained Afghán bowenite seen between crossed Nicols. It is composed of leaves of serpentine (antigorite). On revolving the crossed Nicols, the dark portions become light and the light portions dark.

Fig. 4. Augite partially converted into fibrous serpentine (chrysotile).

Fig. 5. Augite penetrated by large solution veins, filled with fibrous serpentine (chrysotile), continuous with the chrysotile surrounding the augite.

Figs. 1—5 are collotype reproductions of photographs taken by the author. Some of the photographs have been enlarged in order to make the micro-structure visible in the printed plates.

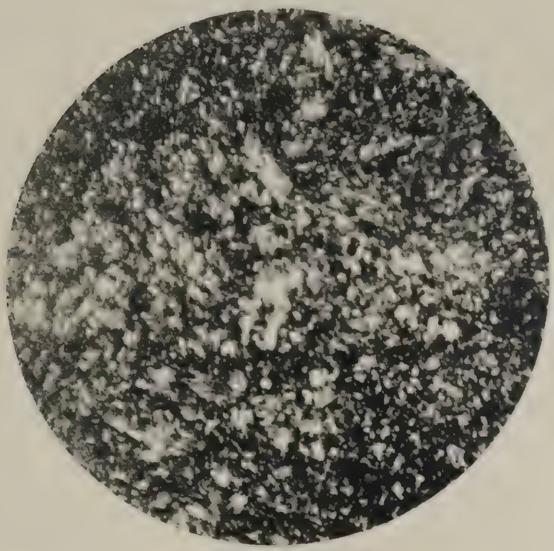

Fig. 1.

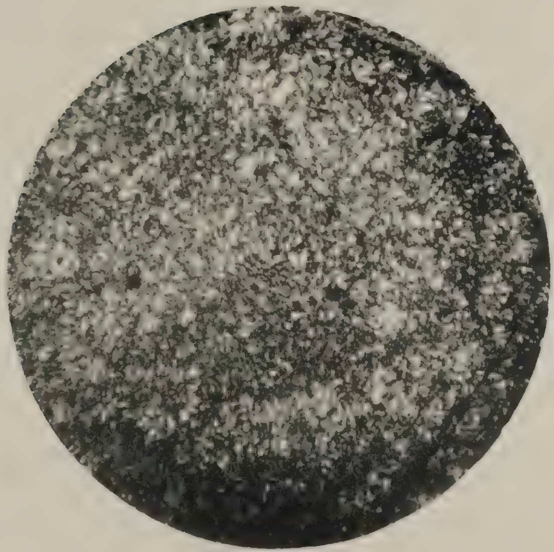

Fig. 2.

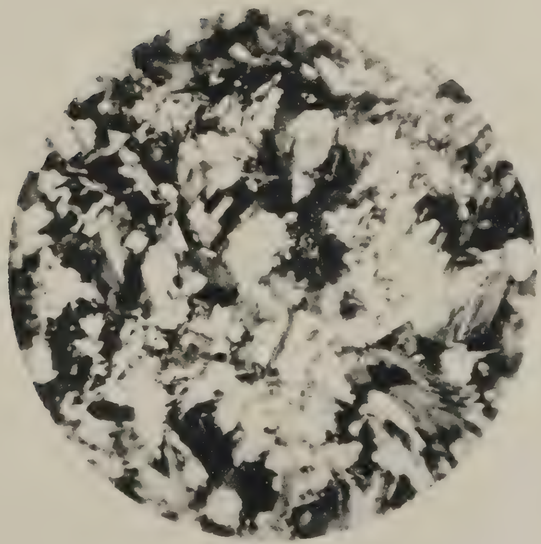

Fig. 3.

PERIDOTES AND SERPENTINES OF N.W. HIMALAYA.

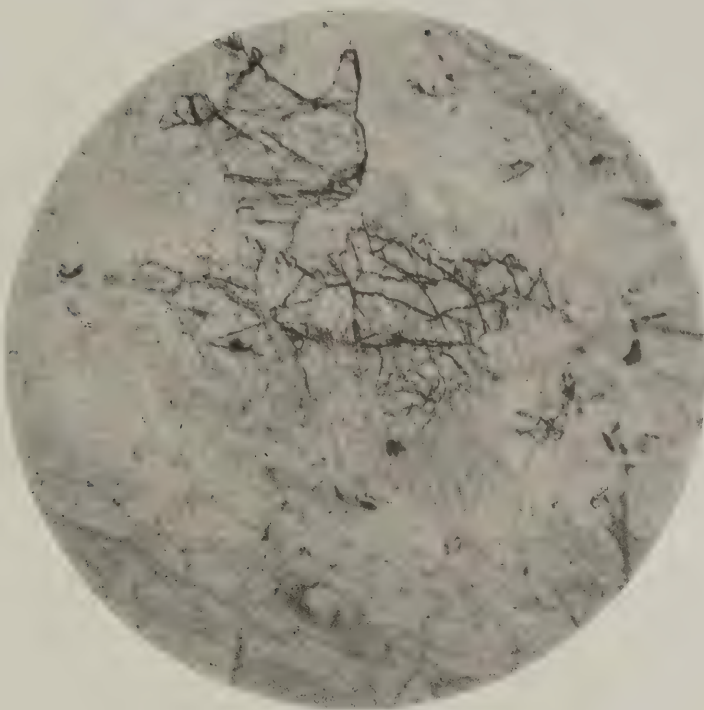

Fig. 4.

Fig. 5.

PERIDOTES AND SERPENTINES OF N.W. HIMALAYA.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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GEOLOGICAL SURVEY OF INDIA.

VOL. XXXI.

Published by order of His Excellency the Governor General of India in Council.

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY.
LONDON: MESSRS. KEGAN PAUL, TRENCH, TRÜBNER & Co.

MDCCCCI

CALCUTTA:
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

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Part 2.—On the most favourable sites for Petroleum explorations in the Harnai district, Baluchistan. The Sapphire Mines of Kashmir. The supposed Matrix of the Diamond at Wajra Karur, Madras. The Sonapet Gold-field. Field Notes from the Shan Hills (Upper Burma). A description of some new species of Syringosphæridæ, with remarks upon their structures, &c.

Part 3.—On the Geology and Economic Resources of the Country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and of the country between it and Khattan (with a map). Report of a Journey through India in the winter of 1888-89, by Dr. Johannes Walther, translated from the German, by R. Bruce Foote. On the Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills (with 3 plans). Further Note on Indian Steatite. Provisional Index of the Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in the Indian Empire (continued from p. 286, Vol. XXII).

Part 4.—Geological sketch of Naini Tal; with some remarks on the natural conditions governing mountain slopes (with a map and plate). Notes on some Fossil Indian Bird Bones. The Darjiling Coal between the Lisu and the Ramthi rivers, explored during season 1890-91 (with a map). The Basic Eruptive Rocks of the Kadapah Area. The Deep Boring at Lucknow. Preliminary Note on the Coal Seam of the Dore Ravine, Hazara (with two plates).

Vol. XXIV, 1891.

Part 1.—Annual report for 1890. On the Geology of the Salt-range of the Punjab, with a re-considered theory of the Origin and Age of the Salt-Marl (with five plates). On veins of Graphite in decomposed Gneiss (Laterite) in Ceylon. Extracts from the Journal of a trip to the Glaciers of the Kabru, Pandim, &c. The Salts of the Sambhar Lake in Rajputana, and of the Saline efflorescence called 'Reh' from Aligarh in the North-Western Provinces. Analysis of Dolomite from the Salt-range, Punjab.

Part 2.—Preliminary Report on the Oil locality near Moghal Kot, in the Sheráni country, Suleiman Hills. On Mineral Oil from the Suleiman Hills. Note on the Geology of the

Lushai Hills. Report on the Coal-fields in the Northern Shan States. Note on the reported Namsèka Ruby-mine in the Mainglôn State. Note on the Tourmaline (Schorle) Mines in the Mainglôn State. Note on a Salt-spring near Bawgyo, Thibaw State.

Part 3.—Boring Exploration *in the* Daltongunj Coal-field, *Palamow* (with a map). *Death of* DR. P. MARTIN DUNCAN. Contributions *to the* study *of the* Pyroxenic varieties *of* Gneiss *and of the* Scapolite-bearing Rocks.

Part 4.—On a Collection of Mammalian Bones from Mongolia. Further note on the Darjiling Coal Exploration. Notes on the Geology and Mineral Resources of Sikkim (with a map). Chemical and Physical notes on rocks from the Salt-range, Punjab (with two plates).

VOL. XXV, 1892.

Part 1.—Annual report for 1891. Report *on the* Geology *of* Thal Chotiáli *and part of the* Mari country (with a map and 5 plates). Petrological Notes *on the* Boulder-bed *of the* Salt-range, Punjáb, Sub-recent *and* Recent Deposits *of the valley plains of* Quetta, Pishin and the Dasht-i-Bedaolat; *with appendices on the* Chamans *of* Quetta; *and the* Artesian water-supply *of* Quetta *and* Pishin (with one plate).

Part 2.—Geology *of the* Safëd Kóh (with 2 plates of sections). Report *on a* Survey *of the* Jherria Coal-field (with a map and 3 section plates) (*out of print*).

Part 3.—*Note on the* Locality *of* Indian Tscheffkinite. Geological Sketch *of the* country north of Bhamo. Preliminary Report *on the* economic resources *of the* Amber *and* Jade mines area *in* Upper Burma. Preliminary Report *on the* Iron-Ores *and* Iron-Industries *of the* Salem District. *On the* Occurrence *of* Riebeckite *in* India. Coal *on the* Great Tenasserim River, Mergui District, Lower Burma.

Part 4.—Report *on the* Oil Springs *at* Moghal Kot *in the* Shirani Hills (with 2 plates). Second Note *on* Mineral Oil *from the* Suleiman Hills. *On a* New Fossil, Amber-like Resin *occurring in* Burma. Preliminary notice *on the* Triassic Deposits *of the* Salt-range.

VOL. XXVI, 1893.

Part 1.—Annual report for 1892. Notes *on the* Central Himalayas (with map and plate). Note *on the occurrence of* Jadeite *in* Upper Burma (with a map). On *the* occurrence *of* Burmite, *a new* Fossil Resin *from* Upper Burma. Report *on the* Prospecting Operations, Mergui District, 1891-92.

Part 2.—Notes *on the* earthquake *in* Baluchistán *on the* 20th December 1892 (with 2 plates). Further Note *on* Burmite, *a new amber-like fossil resin from* Upper Burma. Note *on the* Alluvial deposits *and* Subterranean water-supply *of* Rangoon (with a map).

Part 3.—On th Geology *of the* Sherani Hills (with maps and plates). On Carboniferous Fossils *from* Tenasserim (with 1 plate). *On* a deep Boring *at* Chandernagore. Note *on* Granite *in the districts of* Tavoy *and* Mergui (with a plate).

Part 4.—*On the* Geology *of the country between the* Chappar Rift *and* Harnai *in* Baluchistán (with map and 3 plates). Notes *on the* Geology *of a part of the* Tenasserim Valley *with special reference to the* Tendau-Kamapying Coal-field (with two maps). *On a* Magnetite *from the* Madras Presidency containing Manganese *and* Alumina. *On* Hislopite (Haughton) (with a plate).

VOL. XXVII, 1894.

Part 1.—Annual report for 1893. Report *on the* Bhaganwala Coal-field, Salt-range, Punjab (with map and 2 plates).

Part 2.—Note *on the* Chemical qualities of pertroleum *from* Burma. Note *on the* Singareni Coal-field, Hyderabad (Deccan) (with map and 3 plates of sections). Report *on the* Gohna Landship, Garhwal (with 5 plates and 2 maps).

Part 3.—*On the* Cambrian Formation *of the* Eastern Salt-range (with a plate). The Giridih (Karharbari) Coal-field, *with notes on the* labour and methods of working (with 2 maps and 8 plates of sections). *On the* Occurrence of Chipped (?) Flints *in the* Upper Miocene of Burma (with a plate). Note *on the* Occurrence *of* Velates Schmideliana, Chemn., *and* Provelates grandis, Sow. *sp.*, *in the* Tertiary Formation *of* India *and* Burma (with 2 plates).

Part 4.—Note on the Geology of Wuntho *in* Upper Burma (with a map). Preliminary notice *on the* Echinoids *from the* Upper Cretaceous System of Baluchistán. *On* Highly Phosphatic Mica-Peridotites intrusive *in the* Lower Gondwana Rocks *of* Bengal. *On a* Mica-Hypersthene-Hornblende-Peridotite *in Bengal.*

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. *Cretaceous Formation of Pondicherry. Some* early allusions *to* Barren Island; *with a few remarks thereon.* Bibliography *of* barren Island *and* Narçondam, *from* 1884 *to* 1894; *with some remarks.*

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Vol. XXIX, 1896.

Part 1.—Annual report for 1895. *On the Acicular inclusions in Indian Garnets. On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks* (with 1 plate).

Part 2.—Notes on the Ultra-basic rocks *and* derived minerals *of the* Chalk (Magnesite) hills, *and other localities near* Salem, Madras (with 2—6 plates). *Preliminary notes on some* Corundum localities *in the* Salem and Coimbatore districts, Madras (with 7—9 plates). *On the occurrence of* Corundum *and* Kyanite *in the* Manbhum district, Bengal. *On the papers by* Dr. Kossmat and Dr. Kurtz, *and on the ancient Geography of "Gondwana-land." Note from the Geological Survey of India.*

Part 3.—On some Igneous Rocks *from the* Tochi Valley. *Notes from the Geological Survey of India.*

Part 4.— Report *on the* Steatite mines, Minbu District, Burma. Further notes *on the* Lower Vindhyan (Sub-Kaimur) area *of the* Sone Valley, Rewah. *Notes from the Geological Survey of India.*

Vol. XXX, 1897.

Part 1.—Annual report for 1896. *On* some Norite *and* associated Basic Dykes *and* Lava-flows *in* Southern India (with plates I to II). *The reference of the genus* Vertebraria. *On a* Plant of Glossopteris with part of the rhisome attached, *and on the* structure of Vertebraria (with plates III to V).

Part 2.—The Cretaceous Deposits of Pondicherri (with plates VI to X). *Notes from the Geological Survey of India.*

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Part 4.—On Nemalite from Afghanistan. On a quartz-barytes rock occurring in the Salem District, Madras Presidency (with plate XVIII). Note on a worn femur of Hippopotamus irravadicus, Caut. and Falc., from the Lower Pliocena of Burma (with plates XIX and XX). On the supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. *Notes from the Geological Survey of India.*

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Note.—*The Records cease to be published from the 1st January 1898.*

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